

## THE PERMEABILITIES OF THREE POROUS GRAPHITES

## Final Report

to

National Aeronautics and Space Administration  
 Hampton, Virginia

Contract NAS 1-5448  
 Task Order 2

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## **CONTENTS**

<b>INTRODUCTION . . . . .</b>	<b>1</b>
<b>APPARATUS AND PROCEDURE . . . . .</b>	<b>1</b>
<b>DATA AND RESULTS . . . . .</b>	<b>4</b>
<b>DISCUSSION . . . . .</b>	<b>5</b>
<b>REFERENCES . . . . .</b>	<b>6</b>

# THE PERMEABILITIES OF THREE POROUS GRAPHITES

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## INTRODUCTION

This is the final report under Task Order 2 of Contract NAS 1-5448 for a project to determine the permeabilities of three porous graphites, Grades 25, 45, and 60. The shipping labels identified the specimens as Grades A, B, and C and these designations have been followed throughout this report. Permeabilities of these graphites were measured from room temperature to 1000°F using both nitrogen and helium as the permeating gases.

## APPARATUS AND PROCEDURE

A schematic of the permeability apparatus is shown in Figure 1. Gas was supplied to the specimen from a commercial gas cylinder. The upstream pressure was regulated at 2 to 6 inches of mercury by means of a pressure regulator and a throttling valve. Flow rate was measured with a wet test meter. The total pressure drop through the specimen was measured with a mercury manometer. The specimen was heated in a tubular resistance furnace and its temperature measured by two thermocouples inserted in radially drilled holes in the housing. Power input to the heater was controlled by an autotransformer. Before entering the wet test meter, the gas was cooled to room temperature by passing it through a cooling coil immersed in ice water.

The specimen, which was one inch in diameter by approximately  $\frac{1}{4}$  inch thick, was mounted in a stainless steel housing as shown in Figure 2. The specimen was mounted on a shoulder approximately  $\frac{1}{64}$  inch wide, so that the effective flow diameter was 0.9375 inch. On the upstream side, the specimen holder was bored out to a diameter of 1.50 inches and the annulus between the specimen and the holder was filled with a sealing compound. For the high temperature runs Sauereisen No. 31 cement was used as a sealant. To verify

the sealing qualities of the Sauereisen cement, some evaluations were made on each of the three graphites from room temperature to 500°F using a silicone rubber (Dow Corning RTV-731 Silastic) as the sealant. The silicone rubber had been employed with prior success in room temperature permeability measurements.

Initially, some difficulty was experienced in obtaining a satisfactory seal with the Sauereisen cement due to shrinkage and cracking of the cement on curing. In some cases a satisfactory seal at room temperature would fail at temperatures in the vicinity of 1000°F, as evidenced by a sudden increase in the flow through the specimen. After some experimentation, a satisfactory seal was obtained over the full temperature range by filling the annulus about  $\frac{3}{4}$  full with a dry mix of the Sauereisen, allowing it to cure for 24 hours at room temperature, then applying a fairly wet wash of the cement on the surface. A brass washer was mounted on the surface of the cement while it was still wet. This washer reduced the exposed area of the sealant and served as a secondary seal.

Knife edges and copper gaskets were used to seal the specimen holder within the housing.

During the runs the following data were recorded:

1. Barometric pressure, in. Hg
2. Upstream pressure, in. Hg
3. Flow rate, cm<sup>3</sup>/sec
4. Specimen temperature, °F
5. Temperature at wet test meter, °F
6. Room temperature, °F
7. Downstream pressure (measured at inlet to wet test meter), in. H<sub>2</sub>O.

The procedure in making the runs was as follows: The system was purged for about one hour to saturate the gas in the wet test meter. The upstream pressure was adjusted to the desired level and the temperature allowed to stabilize before taking data. All runs were made in both nitrogen and helium. When changing from one gas to the other the system was purged for about 30 minutes before taking a reading. Four readings were taken at each pressure level to monitor that steady state conditions had been obtained.

The admittance of the specimen was calculated using the equation

$$K_{mv} = \frac{P_m L Q_m}{\Delta P} \quad (1)$$

where

$P_m$  = mean pressure in specimen

$Q_m$  = flow rate through specimen based on mean pressure,  $\text{cm}^3/\text{sec}$

$L$  = thickness of specimen, cm

$A$  = cross sectional area of specimen,  $\text{cm}^2$

$\Delta P$  = pressure drop across specimen

Since the flow rate was measured at the meter, it had to be corrected for conditions at the specimen. This was performed using the continuity equation as follows:

$$W = \rho A V = \rho Q = \text{constant} \quad (2)$$

where

$\rho$  = gas density

$A$  = flow area

$V$  = velocity

from the perfect gas law

$$\rho = \frac{P}{RT} \quad (3)$$

where

$R$  = the gas constant

$T$  = absolute temperature

then substituting in equation (2)

$$\left( \frac{P_m Q_m}{RT_m} \right)_{\text{specimen}} = \left( \frac{P Q}{RT} \right)_{\text{meter}} \quad (4)$$

then

$$P_m Q_m = PQ \left( \frac{T_{\text{specimen}}}{T_{\text{meter}}} \right) \quad (5)$$

Thus, the flow rates measured at the wet test meter were corrected to the flow rates that existed for the pressures and temperatures at the specimen.

## DATA AND RESULTS

The data for Graphite A are shown in Figure 3 and Tables 1 and 2. As shown in Figure 3, the values at room temperature ranged from about  $2200 \text{ cm}^2/\text{sec}$  for nitrogen to about  $3100 \text{ cm}^2/\text{sec}$  for helium. At  $1000^\circ\text{F}$  the values all agreed within about 10 percent, averaging about  $3000 \text{ cm}^2/\text{sec}$ .

The data for Graphite B are shown in Figures 4 and 5 and Tables 3, 4, and 5. As shown in the figures the curves exhibited about the same character as those for Graphite A, the lowest values at room temperature being measured in nitrogen at an upstream pressure of 6 in. Hg. At  $1000^\circ\text{F}$  the lowest values were for helium. At both temperatures the values ranged from about  $1150 \text{ cm}^2/\text{sec}$  to  $1500 \text{ cm}^2/\text{sec}$ .

The data for Graphite C are shown in Figure 6 and Tables 6, 7, and 8. This graphite exhibited the lowest permeabilities of the three grades tested, the values ranging from about  $340$  to  $480 \text{ cm}^2/\text{sec}$  at room temperature, and from  $250$  to  $380 \text{ cm}^2/\text{sec}$  at  $1000^\circ\text{F}$ .

To investigate the flow characteristics at higher pressure drops, some evaluations were made at room temperature on a specimen of Graphite B. For these determinations the wet test meter was replaced with a rotameter which, although less accurate than the wet test meter, did permit the measurement of higher flows. The data are shown in Figure 7 and Table 9. Observe that the admittance generally increased with increasing pressure. The type of flow can be determined from a log-log plot of  $PQ$  versus  $P\Delta P$ . From the theory of flow through porous media, the product  $PQ$  is directly proportional to  $P\Delta P$ , i.e., the slope of the curve is unity if the flow in the pores is laminar. If turbulent flow exists, the flow rate is proportional to the  $\frac{1}{2}$  power of  $P\Delta P$  (slope = 0.5). For the transition region in which both types of flow exist, the exponent, or slope of the curve, will fall between 0.5 and unity.<sup>1</sup>

Such a plot is presented in Figure 8, showing that over the range of pressures covered the flow is laminar for both gases, possibly approaching turbulent flow for nitrogen at the upper end.

## DISCUSSION

In general, the permeability varies with pressure and temperature in a fashion that is indicative of the type of flow through the specimen. The admittance,  $K_{mv}$ , can be represented as the sum of two terms, as follows:

$$K_{mv} = K_0 \sqrt{RT} + K_1 \frac{P_m}{\eta} \quad (5)$$

where  $\eta$  is the viscosity of the gas.

The first term represents the molecular portion and the second term the viscous portion. If viscous flow predominates, the curve increases linearly with pressure and decreases with temperature because of the viscosity effect. If molecular flow predominates, the admittance will remain constant with pressure and increase with an increase in temperature, provided  $K_0$  remains constant. Reference to Figure 7 shows that for Graphite B at room temperature and at mean pressures below about 35 in. Hg, corresponding to upstream gage pressures below 6 in. Hg, the admittance for both gases decreased or remained constant with pressure. Hence, flow was predominantly molecular. The data for Graphites A and B, shown in Figures 3 through 5, also exhibited this trend at room temperature, while at 1000°F there was some pressure effect, suggesting viscous flow at the higher temperature. For Graphite C, the permeability increased with increasing pressure and decreased with increasing temperature, suggesting viscous flow over the full temperature range.

It appears that for all conditions of the tests, flow was laminar.

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1. Creutz, E.: Turbulent and Transition Gas Flow in Porous Media.  
Nuclear Science and Engineering, Vol. 20, 1964, pp. 28-44.

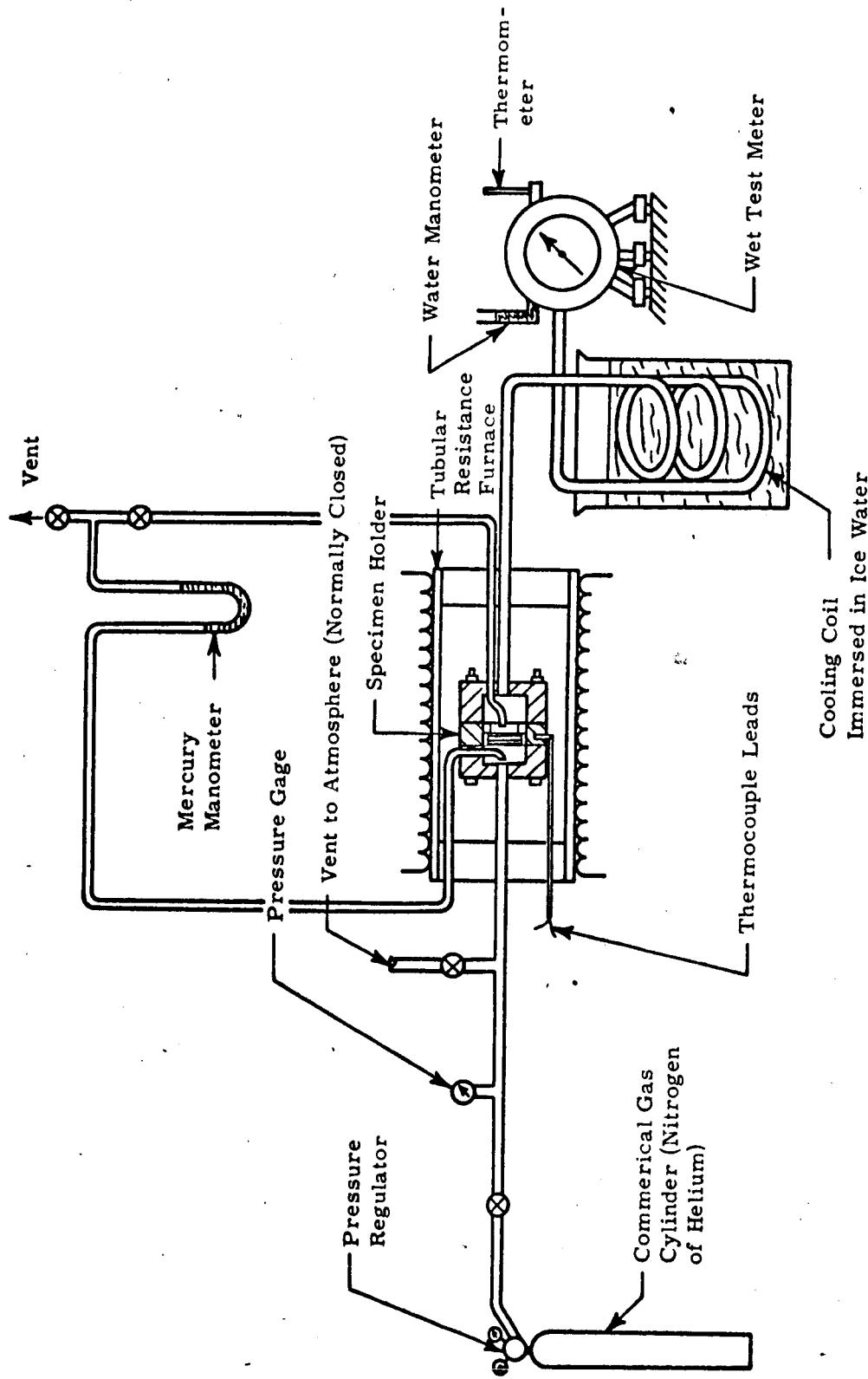


Figure 1. Schematic of the Permeability Apparatus

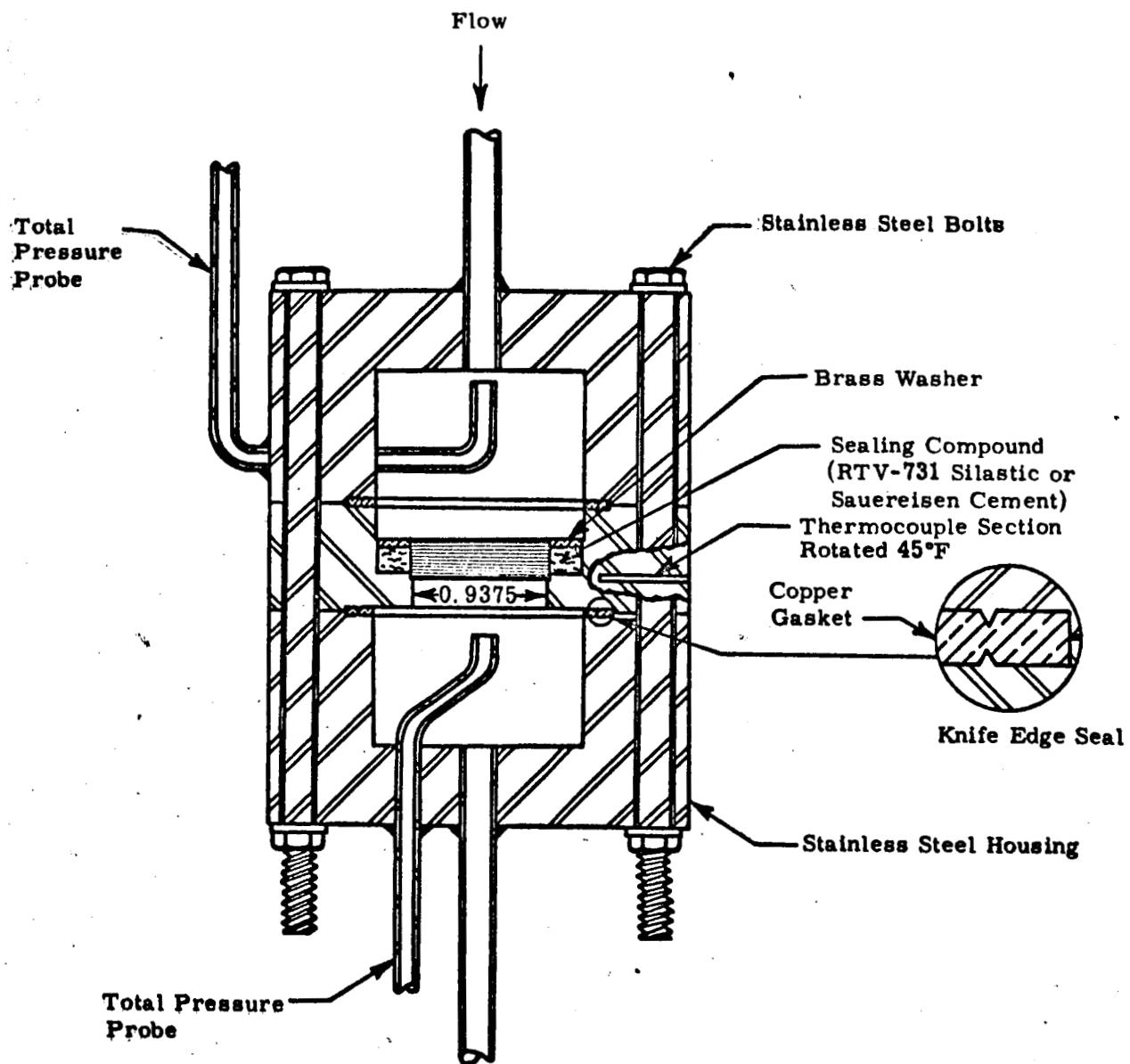


Figure 3. Details of Permeability Specimen Holder

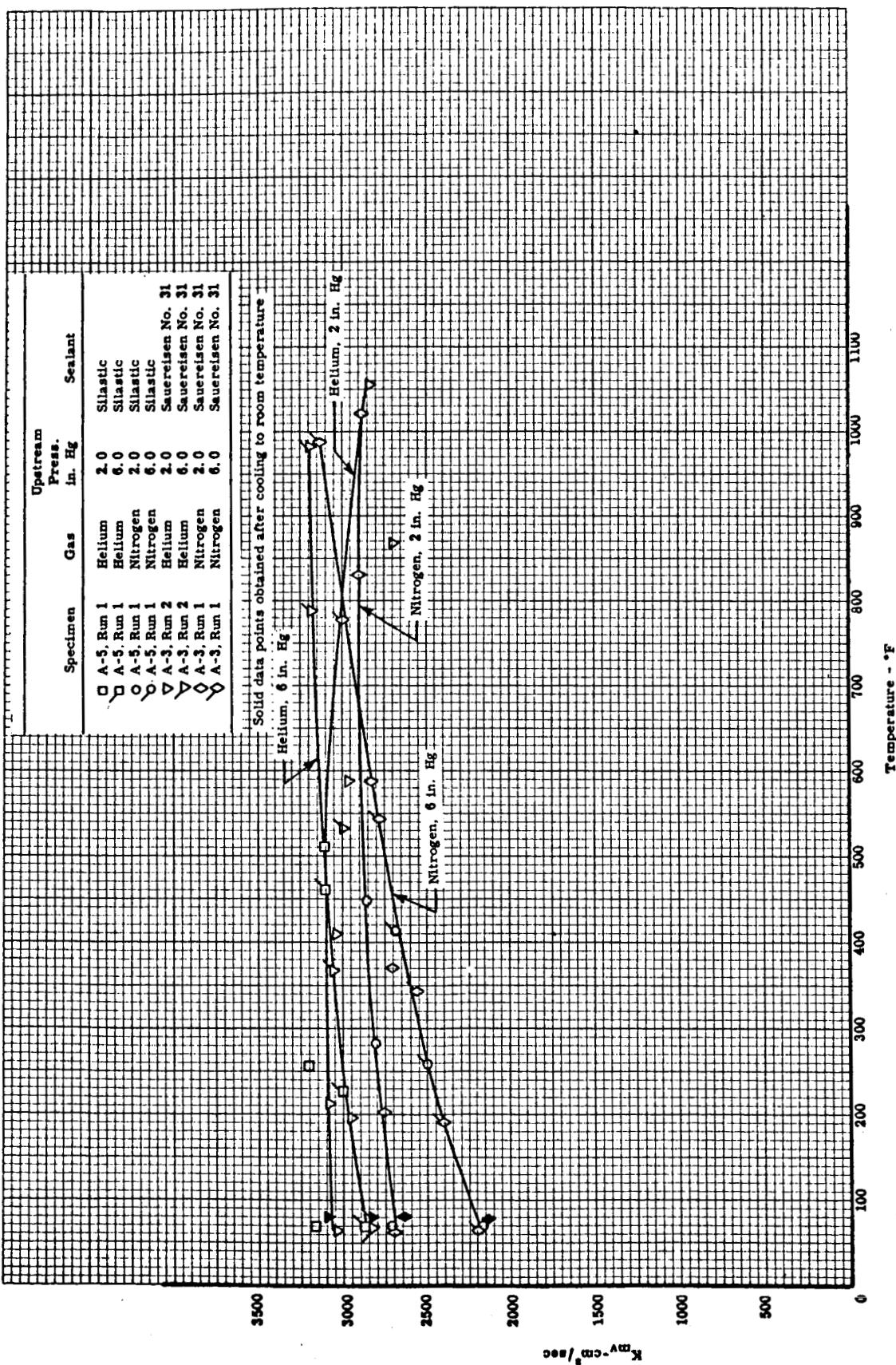


Figure 3. The permeability of porous graphite Type A

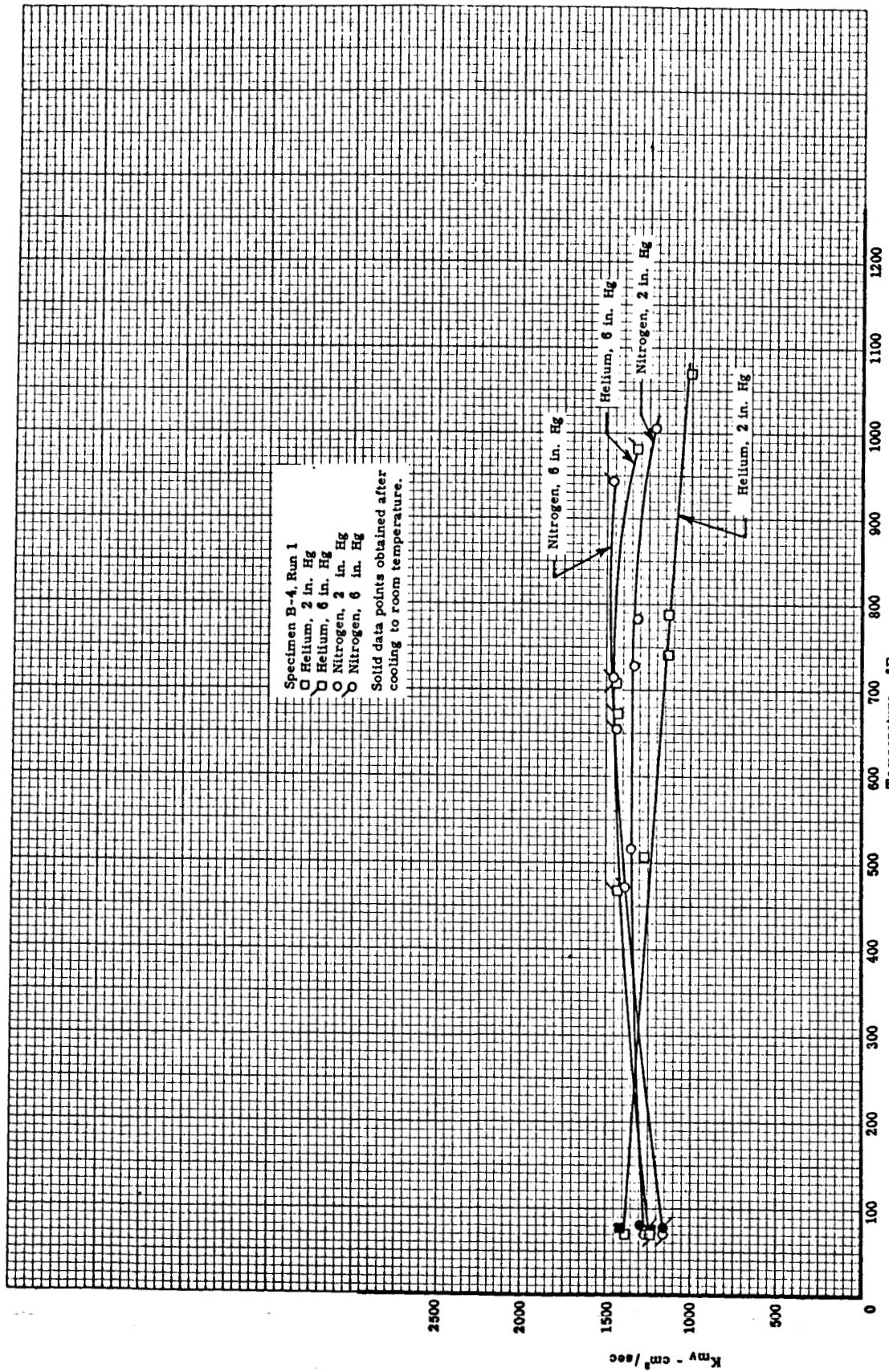


Figure 4. The permeability of porous graphite Type B

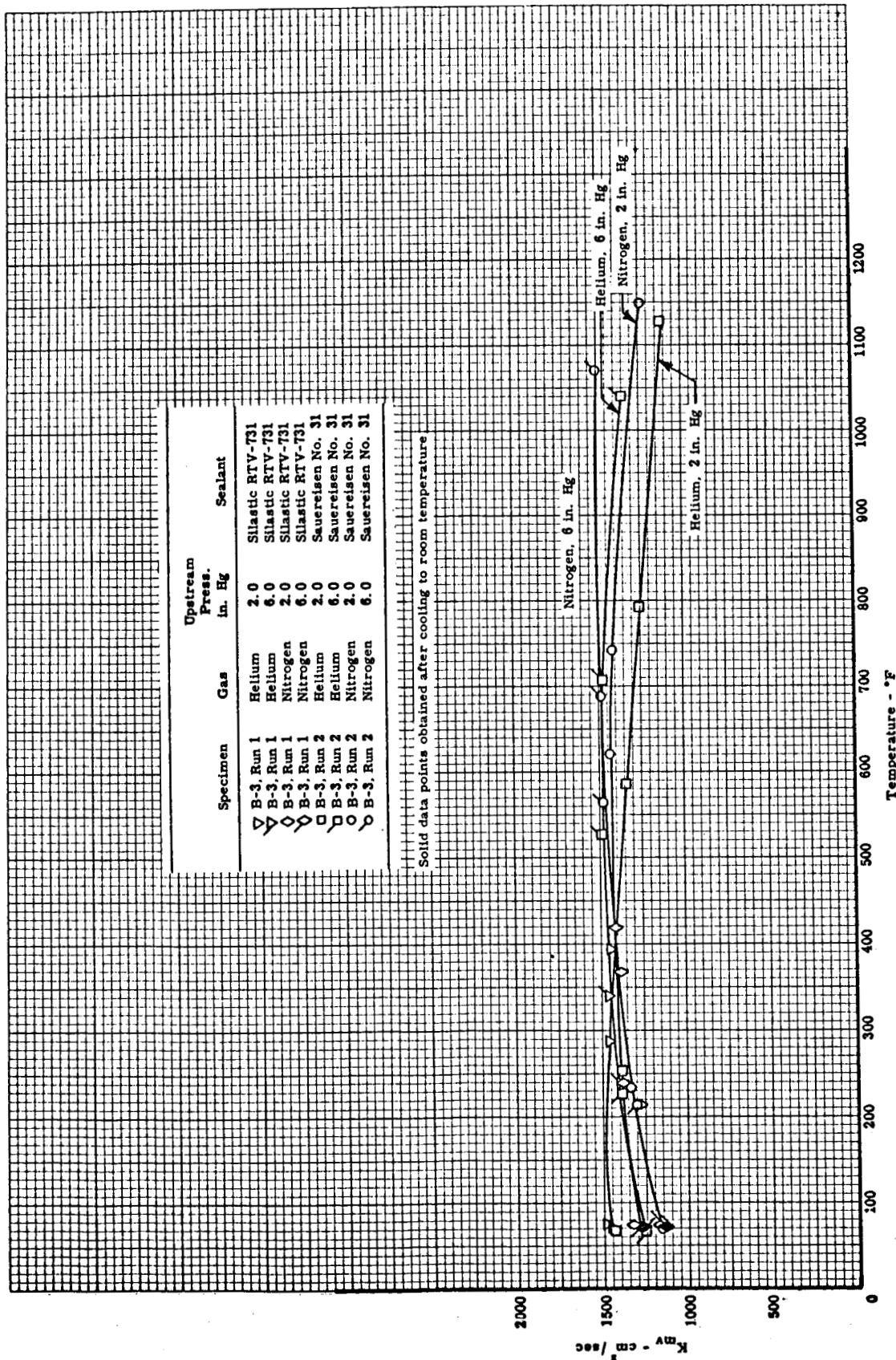


Figure 5. The permeability of porous graphite Type B

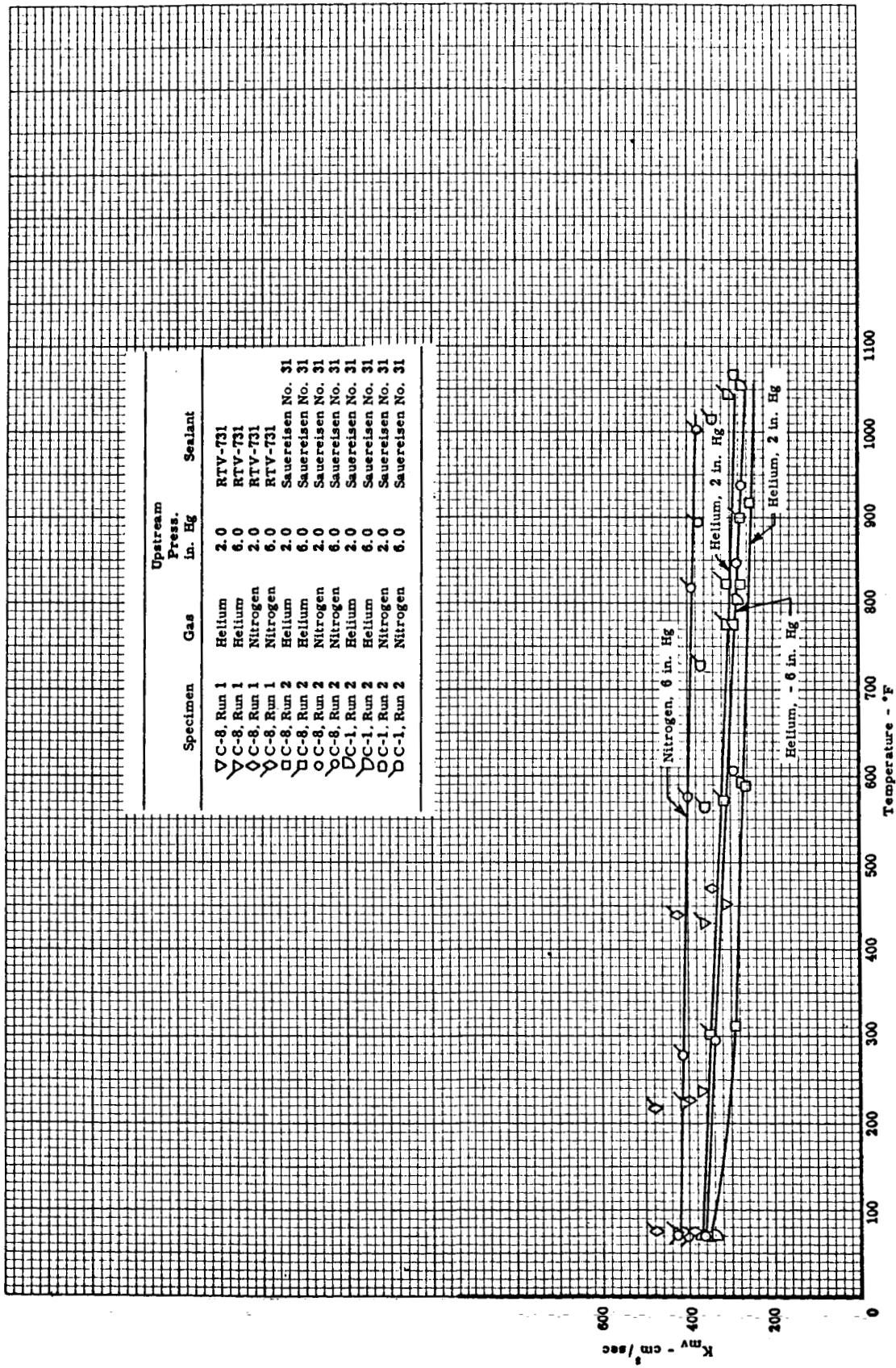


Figure 6. The permeability of porous graphite Type C

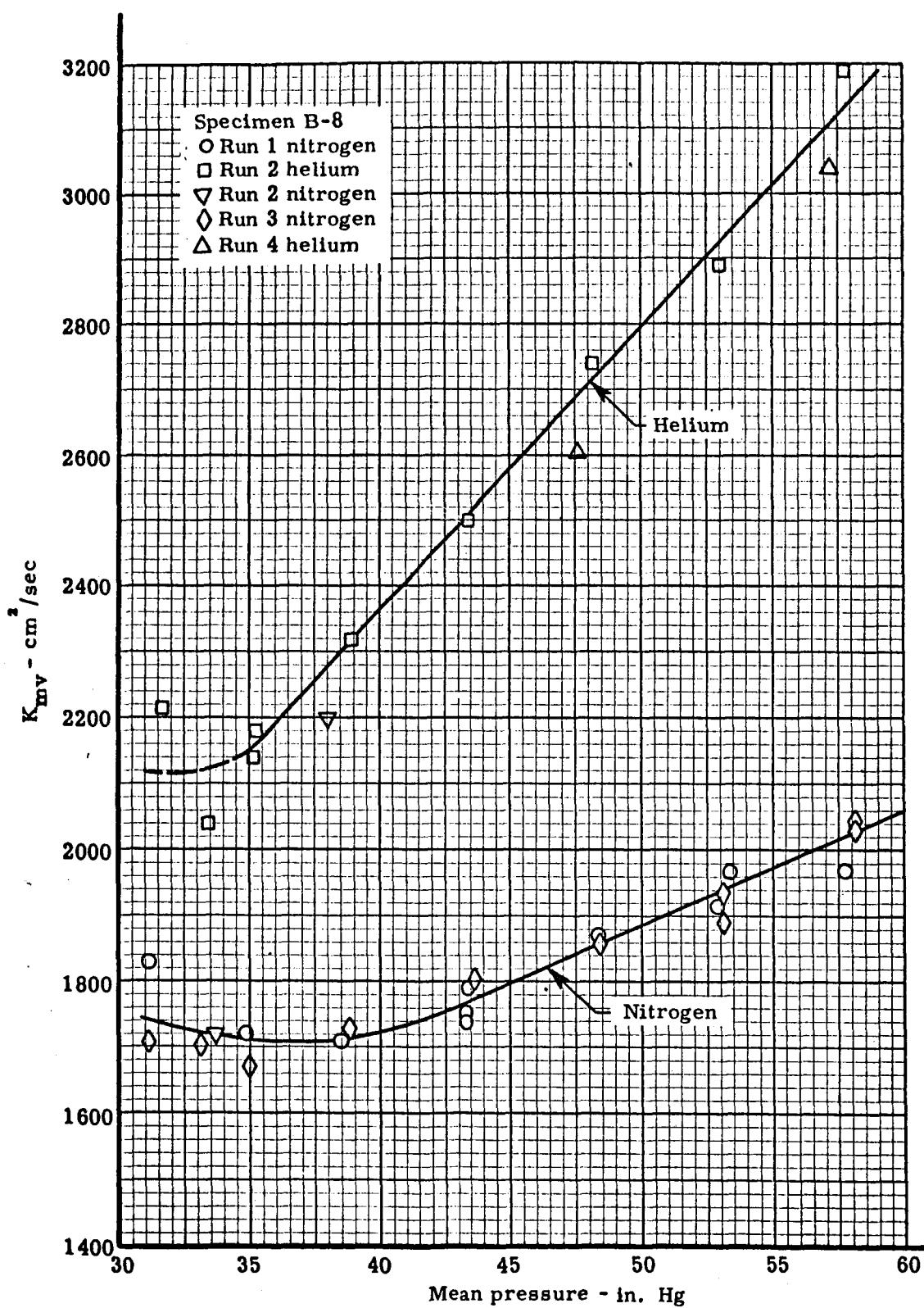


Figure 7. Permeability of Graphite B at room temperature showing effect of pressure

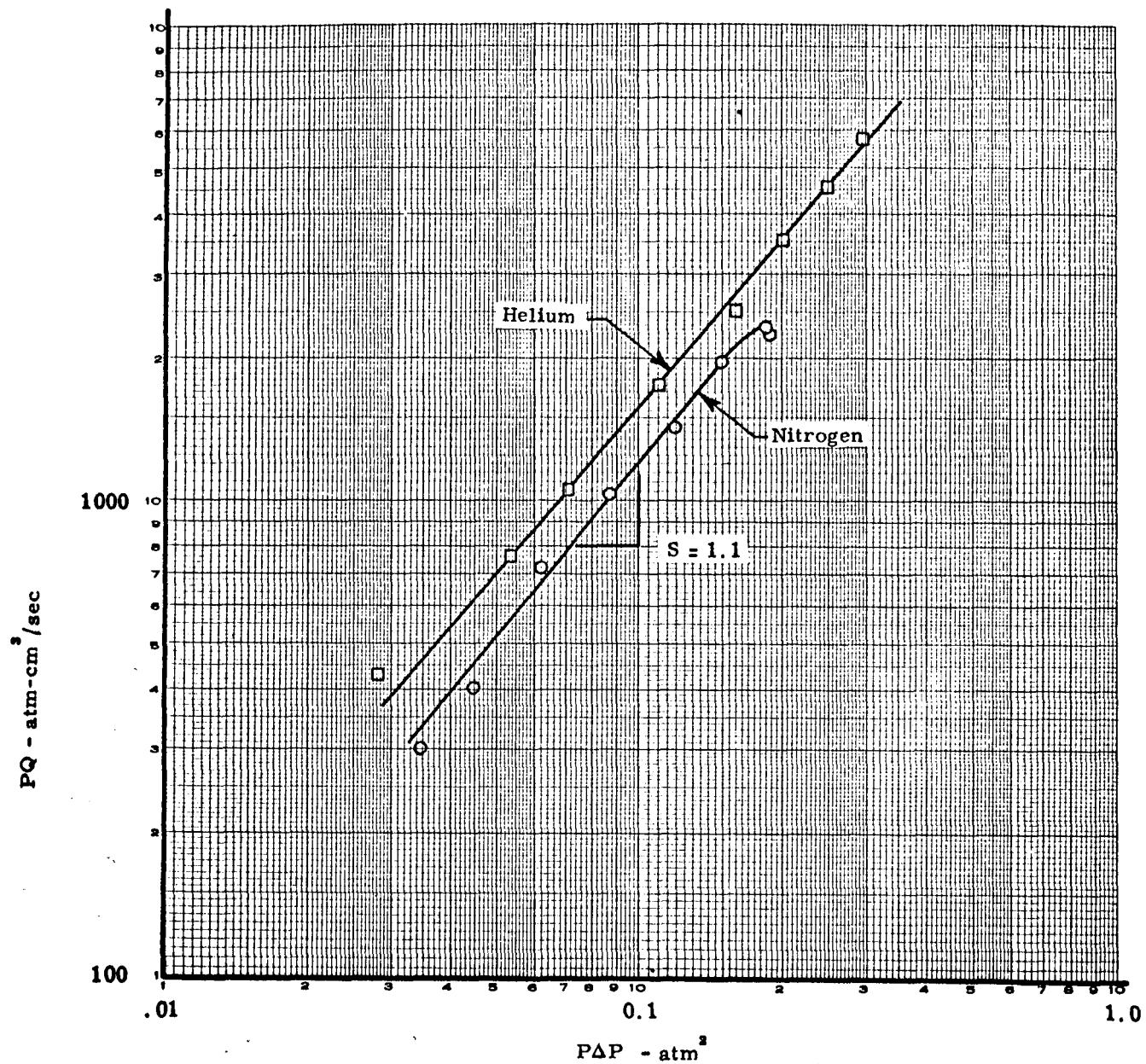


Figure 8. Product  $PQ$  in  $\text{atm-cm}^3/\text{sec}$ , versus  $P\Delta P$  in  $\text{atm}^3$  for Graphite B, Specimen 7

TABLE I  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN A-3, RUN 2

Time	Permeating gas	Atm. press. $P_0$ in. Hg	Upstream gage press. $P_1$ in. Hg	Downstream gage press. $P_2$ in. Hg <sup>(a)</sup>	Pressure drop through specimen in. Hg	Mean press. $P_m$ in. Hg	Temperature, °F		Flow rate cm <sup>3</sup> /sec <sup>(d)</sup>	$K_{mv}$ cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 12:50, Read 1:50 1:57	nitrogen nitrogen	30.18 30.18	2.0 6.0	0.056 0.220	.37 .83	31.97 35.73	64.5 64.5	69.0 69.0	225.1 417.3	2700 2200	
Begin Purge 3:05, Read 2:25 2:29 4:15 4:20	helium helium helium helium	30.18 30.18 30.12 30.12	2.0 6.0 2.0 6.0	0.037 0.184 0.037 0.171	.66 1.23 .68 1.40	31.87 35.53 31.78 35.42	66.0 66.0 211 195	69.0 68.5 68.5 68.0	303.3 806.8 380.2 769.5	3040 2840 3080 2960	
Begin Purge 4:32, Read 4:52 5:05	nitrogen nitrogen	30.12 30.12	2.0 6.0	0.051 0.206	.44 .90	31.90 35.07	201 190	68.0 67.8	215.5 403.4	2780 2410	
Purge overnight with helium, Read 7:51 a. m. 8:10	helium helium	30.25 30.25	2.0 6.0	0.029 0.164	.82 1.85	31.83 35.43	409 366	73.0 70.5	350.1 741.3	3040 3060	
Begin Purge 8:16, Read 8:36 8:51 11:04 11:20	nitrogen nitrogen nitrogen nitrogen	30.25 30.25 30.25 30.25	2.0 6.0 2.0 6.0	0.051 0.199 0.048 0.184	.53 1.00 .62 1.13	31.98 35.75 31.94 35.68	370 342 587 542	65.5 70.0 70.0 70.0	209.2 389.0 204.6 380.6	2710 2570 2830 2780	
Begin Purge 11:26, Read 12:36 12:50 2:45 2:57	helium helium helium helium	30.25 30.25 30.20 30.20	2.0 6.0 2.0 6.0	0.029 0.140 0.029 0.132	.96 1.87 1.16 2.23	31.77 35.31 31.62 35.06	588 531 869 787	68.2 69.0 68.5 68.5	330.0 687.3 287.2 690.6	2960 3000 2700 3180	
Begin Purge 3:00, Read 3:20 3:43 4:40 4:53	nitrogen nitrogen nitrogen nitrogen	30.20 30.20 30.16 30.16	2.0 6.0 2.0 6.0	0.044 0.184 0.044 0.176	.73 1.27 .81 1.40	31.83 35.56 31.75 35.46	830 777 1021 989	68.2 68.0 68.2 68.2	199.7 373.0 192.9 367.8	2900 3000 2890 3140	
Begin Purge 5:00, Read 5:18 5:31	helium helium	30.16 30.16	2.0 6.0	0.018 0.265	1.30 2.48	31.51 34.92	1055 981	68.2 68.2	254.6 661.6	2840 3180	
Power off 5:33 7:45 a. m. 7:50	helium helium	30.28 30.28	2.0 6.0	0.059 0.191	.56 1.25	32.00 35.65	80 80	71.0 70.5	391.1 795.4	3100 2830	
Begin Purge 7:55, Read 8:37 8:41	nitrogen nitrogen	30.28 30.28	2.0 6.0	0.059 0.110	.38 .84	32.00 35.86	80 78	70.5 70.0	226.5 406.8	2640 3140	

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.252 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 2  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN A-8, RUN 1

Time	Permeating gas	Atm. press. P <sub>0</sub> in. Hg	Upstream gage press. P <sub>1</sub> in. Hg	Downstream gage press. P <sub>2</sub> in. Hg (s)	Pressure drop through specimen in. Hg	Mean press. P <sub>m</sub> in. Hg	Temperature, °F		Flow rate cm <sup>3</sup> /sec <sup>(d)</sup>	K <sub>mv</sub> cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 8:10, Read 10:30 10:24	helium helium	30.12 30.12	2.0 6.0	0.015 0.007	.55 1.23	31.85 35.48	70.0 70.0	70.0 70.0	403.4 616.4	3173 2860	
Begin Purge 10:35, Read 11:13 11:16 2:05 2:18	nitrogen nitrogen nitrogen nitrogen	30.12 30.12 30.06 30.06	2.0 6.0 2.0 6.0	0.059 0.221 0.051 0.213	.37 .84 .48 .95	31.94 35.70 31.82 35.58	70.0 70.0 282 289	69.2 69.2 68.5 68.0	231.7 417.7 221.9 403.4	2716 2170 2810 2500	
Begin Purge 3:22, Read 2:47 2:59 4:26 4:36	helium helium helium helium	30.06 30.06 30.06 30.06	2.0 6.0 2.0 6.0	0.037 0.007 0.029 0.015	.70 1.46 .90 1.77	31.71 35.33 31.61 35.18	256 228 514 461	67.5 67.0 67.0 66.8	382.7 777.9 350.5 729.8	3210 3000 3110 3110	
Begin Purge 4:40, Read 5:03 5:18	nitrogen nitrogen	30.06 30.06	2.0 6.0	0.051 0.199	.55 1.05	31.78 35.63	448 411	66.5 66.0	211.3 390.2	2860 2660	

1. Used RTV-731 Silastic Sealant
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 3  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN B-3, RUN 1

Time	Permeating gas	Atm. press. $P_a$ in. Hg	Upstream gage press. $P_1$ in. Hg	Downstream gage press. $P_2$ ( <sup>a</sup> ) in. Hg	Pressure drop through specimen in. Hg	Mean press. $P_m$ in. Hg	Temperature, °F		Flow rate cm <sup>3</sup> /sec ( <sup>b</sup> )	$K_{pnv}$ cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 9:50, Read 12:32 12:40	nitrogen nitrogen	30.07 30.07	2.0 6.0	0.051 0.199	.70 1.50	31.72 35.32	73.5 73.5	67.00 66.75	210 397	1322- 1172	Room temperature 73.5°F
Begin Purge 12:49, Read 1:35 1:40 4:00 4:27	helium helium helium helium	30.07 30.07 30.00 30.00	2.0 6.0 2.0 6.0	0.040 0.077 0.037 0.129	1.00 2.50 1.25 2.83	31.57 34.62 31.37 34.58	73.5 73.5 268 238	66.75 66.25 67.75 66.50	330 730 298 686	1493 1290 1466 1399	
Begin Purge 4:32, Read 4:48 5:14 10:57 11:24	nitrogen nitrogen nitrogen nitrogen	30.00 30.00 30.01 30.01	2.0 6.0 2.0 6.0	0.044 0.187 0.040 0.173	.62 1.66 .96 1.86	31.59 35.12 31.53 35.08	238 214 418 368	66.25 66.00 66.00 65.50	198 382 188 373	1391 1286 1410 1365	Room temperature 73°F
Begin Purge 11:29, Read 12:30 12:55	helium helium	30.01 30.01	2.0 6.0	0.018 0.114	1.33 3.03	31.34 34.49	394 340	66.00 65.00	273 666	1446 1458	Power off 12:57
Begin Purge 9:10, Read 10:14 10:20	helium helium	30.00 30.00	2.0 6.0	0.033 0.114	1.00 2.50	31.50 34.75	71.0 69.0	70.00 69.75	337 730	1465 1268	Room temperature 70°F
Begin Purge 10:24, Read 12:21 12:28	nitrogen nitrogen	30.00 30.00	2.0 6.0	0.048 0.195	.70 1.50	31.65 35.25	69.0 69.0	69.25 69.00	210 394	1303 1146	

1. Used RTV-731 Silastic Sealant
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 4  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN B-3, RUN 2

Time	Permeating gas	Atm. press. $P_0$ in. Hg	Upstream gage press. $P_u$ in. Hg	Downstream gage press. $P_d$ in. Hg (P)	Pressure drop through Specimen in. Hg	Mean press. $P_m$ in. Hg	Temperature, °F		Flow rate ( $\mu$ ) cm <sup>3</sup> /sec	$K_{mv}$ cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 11:06, Read 3:57 4:02	nitrogen nitrogen	29.96 29.96	2.0 6.0	0.048 0.195	.70 1.48	31.61 35.22	69.0 69.0	73.00 73.00	208 399	1279 1166	Room temperature 72°F
Begin Purge 4:06, Read 4:30 4:33 12:15 12:28	helium helium helium helium	29.96 29.96 29.96 29.96	2.0 6.0 2.0 6.0	0.026 0.132 0.018 0.125	1.00 2.47 1.23 2.80	31.46 34.72 31.36 34.58	68.0 68.0 251 226	73.00 72.75 72.75 72.00	336 724 294 692	1442 1262 1362 1386	Power on 4:36 p. m.
Begin Purge 12:32, Read 1:37 1:50 7:43 7:58	nitrogen nitrogen nitrogen nitrogen	29.98 29.98 30.01 30.01	2.0 6.0 2.0 6.0	0.040 0.187 0.033 0.158	.82 1.66 1.10 2.10	31.57 35.15 31.46 34.96	232 214 620 564	71.00 71.00 71.25 71.00	194 390 179 370	1337 1300 1437 1481	Room temperature 71°F
Begin Purge 8:02, Read 8:58 9:11 3:18 3:29	helium helium helium helium	30.01 30.01 29.91 29.91	2.0 6.0 2.0 6.0	0.011 0.092 0.011 0.077	1.45 3.40 1.58 3.75	31.28 34.31 31.12 34.03	586 527 792 708	71.00 70.75 73.75 73.25	235 628 196 584	1349 1493 1257 1478	Room temperature 75°F
Begin Purge 3:33, Read 4:18 4:33 7:50 8:03	nitrogen nitrogen nitrogen nitrogen	29.91 29.91 30.00 30.00	2.0 6.0 2.0 6.0	0.026 0.151 0.018 0.121	1.17 2.25 1.46 2.73	31.32 33.68 31.27 34.63	741 686 1149 1070	73.50 73.25 74.00 74.00	170 359 139 329	1415 1490 1244 1503	Room temperature 74.25°F
Begin Purge 8:07, Read 8:48 10:03	helium helium	30.00 30.00	2.0 6.0	0.004 0.055	1.80 4.42	31.10 33.79	1128 1039	74.75 74.25	157 490	1122 1352	Power off 10:04, Slow purge, during cool down
Begin Purge 8:46, Read 9:56 10:01	helium helium	29.93 29.93	2.0 6.0	0.022 0.129	1.00 2.60	31.43 34.68	70.25 70.25	70.50 70.00	332 718	1437 1347	Room temperature 70.25°F
Begin Purge 10:04, Read 10:38 10:43	nitrogen nitrogen	29.93 29.93	2.0 6.0	0.048 0.195	.70 1.80	31.58 35.18	70.25 70.25	70.50 70.00	332 390	1287 1132	

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.353 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 6  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN B-4, RUN 1

Time	Permeating gas	Atm. press. P <sub>a</sub> in. Hg	Upstream gage press. P <sub>1</sub> in. Hg	Downstream gage press. P <sub>2</sub> in. Hg (s)	Pressure drop through specimen in. Hg	Mean press. P <sub>m</sub> in. Hg	Temperature, °F		Flow rate cm <sup>3</sup> /sec (s)	K <sub>mv</sub> cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 8:35, Read 9:51 9:56	helium helium	30.09 30.09	2.0 6.0	0.026 0.121	1.00 2.48	31.59 34.85	70 70	70.0 70.0	318 703	1384 1237	Room temperature 71°F
Begin Purge 10:00, Read 10:20 10:24 1:34 1:54	nitrogen nitrogen nitrogen nitrogen	30.09 30.09 30.00 30.00	2.0 6.0 2.0 6.0	0.048 0.195 0.033 0.092	.70 1.48 1.03 2.0	31.74 35.35 31.48 35.00	88 68 517 472	70.0 70.0 71.0 70.0	204 393 174 362	1289 1162 1349 1384	Room temperature 73°F
Begin Purge 1:58, Read 2:27 2:41 4:46 5:00	helium helium helium helium	30.00 30.00 30.02 30.02	2.0 6.0 2.0 6.0	0.011 0.092 0.007 0.077	1.40 3.27 1.57 3.75	31.30 34.36 31.23 34.14	508 469 787 708	70.0 70.0 71.0 70.0	225 614 176 567	1273 1431 1142 1448	Room temperature 71°F
Begin Purge 5:05, Read 5:25 5:46 7:58 8:13	nitrogen nitrogen nitrogen nitrogen	30.02 30.02 30.08 30.08	2.0 6.0 2.0 6.0	0.026 0.151 0.026 0.147	1.16 2.23 1.20 2.38	31.44 34.90 31.48 34.94	729 655 783 713	70.0 69.0 70.0 70.0	159 350 155 345	1335 1442 1318 1463	Slow nitrogen purge over night Room temperature 70°F
Begin Purge 8:18, Read 8:50 9:04 12:39 12:54	helium helium helium helium	30.08 30.08 30.08 30.08	2.0 6.0 2.0 6.0	0.011 0.081 0.007 0.062	1.56 3.68 1.75 4.30	31.30 34.24 31.18 33.91	742 673 1069 981	70.0 69.0 71.0 70.0	180 562 140 478	1138 1426 1002 1316	Room temperature 71°F
Begin Purge 12:58, Read 1:31 1:45 7:52 7:56	nitrogen nitrogen nitrogen nitrogen	30.06 30.06 30.12 30.12	2.0 6.0 2.0 6.0	0.022 0.132 0.044 0.195	1.36 2.56 .70 1.80	31.38 34.78 31.77 35.37	1005 944 80 79	70.0 70.0 69.0 69.0	138 324 204 391	1219 1462 1296 1164	Power off 1:45, slow nitrogen purge over night, Room temp. 69°F
Begin Purge 8:00, Read 8:28 8:29	helium helium	30.12 30.12	2.0 6.0	0.026 0.121	1.00 2.48	31.62 34.88	76 74	69.0 69.0	321 697	1417 1240	Gas off

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 6  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN C-8, RUN 1

Time	Permeating gas	Atm. press. P <sub>0</sub> in. Hg	Upstream gage press. P <sub>1</sub> in. Hg	Downstream gage press. P <sub>2</sub> in. Hg (a)	Pressure drop through specimen in. Hg	Mean press. P <sub>M</sub> in. Hg	Temperature, °F		Flow rate cm <sup>3</sup> /sec (4)	K <sub>MV</sub> cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 8:10, Read 9:12 9:17	nitrogen nitrogen	29.96 29.96	2.0 6.0	0.018 0.107	1.48 2.80	31.22 34.56	75.0 75.0	73.50 73.25	133 308	389 478	Room temperature 75°F
Begin Purge 9:20, Read 10:00 10:04 2:25 2:40	helium helium helium helium	29.96 29.96 29.88 29.88	2.0 6.0 2.0 6.0	0.007 0.040 0.004 0.039	1.60 4.36 1.80 4.80	31.11 33.78 30.98 33.48	75.0 75.0 236 222	73.75 73.50 74.25 74.00	160 431 119 358	410 428 372 412	Room temperature 76.25°F
Begin Purge 2:43, Read 3:25 3:40 10:54 11:11	nitrogen nitrogen nitrogen nitrogen	29.88 29.88 29.94 29.94	2.0 6.0 2.0 6.0	0.016 0.088 0.007 0.070	1.60 3.20 1.75 4.10	31.08 34.28 31.08 33.89	226 216 469 439	74.00 74.00 70.25 70.00	115 280 80 239	399 480 347 428	Room temperature 70°F
Begin Purge 11:16, Read 11:51 12:08	helium helium	29.94 29.94	2.0 6.0	0.004 0.018	1.85 5.30	31.01 33.20	453 430	70.00 69.75	77 266	310 365	Power off 12:11 Helium off 12:11
Begin Purge 11:35, Read 12:35 12:39	helium helium	30.08 30.08	2.0 6.0	0.007 0.044	1.70 4.40	31.23 33.68	69.0 69.0	69.50 69.50	155 423	396 418	Room temperature 69°F
Begin Purge 12:43, Read 1:10 1:14	nitrogen nitrogen	30.08 30.08	2.0 6.0	0.018 0.107	1.50 2.90	31.33 34.63	69.0 69.0	70.00 70.00	132 302	383 454	

1. Used RTV-731 Silastic Sealant for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 7  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN C-8, RUN 2

Time	Permeating gas	Atm. press. $P_0$ in. Hg	Upstream gage press. $P_1$ in. Hg	Downstream gage press. $P_2$ (t) in. Hg	Pressure drop through specimen in. Hg	Mean press. $P_m$ in. Hg	Temperature, °F		Flow rate ( $\ell$ ) cm³/sec	$K_{mv}$ cm³/sec	Remarks
							Spec.	Meter			
Begin Purge 8:45, Read 9:45 9:50	nitrogen nitrogen	30.13 30.13	2.0 6.0	0.018 0.099	1.60 3.00	31.38 34.63	70.0 70.0	70.00 70.00	125 295	363 430	Room temperature 70°F
Begin Purge 9:55, Read 10:20 10:25 2:48 3:04	helium helium helium helium	30.13 30.13 30.04 30.04	2.0 6.0 2.0 6.0	0.007 0.037 0.004 0.022	1.70 4.60 1.85 5.33	31.28 33.63 31.11 33.42	70.0 70.0 75.50 76.75	70.00 70.00 86 295	146 398 86 349	374 377 295 349	Power on 10:20 Room temperature 81°F
Begin Purge 3:06, Read 3:55 4:10 8:20 6:39	nitrogen nitrogen nitrogen nitrogen	30.04 30.04 30.02 30.02	2.0 6.0 2.0 6.0	0.011 0.077 0.004 0.051	1.70 3.70 1.80 4.50	31.19 34.19 31.12 33.77	295 277 608 576	77.00 77.00 82.50 82.35	94 257 62 216	338 415 294 309	Room temperature 83°F
Begin Purge 8:44, Read 9:14 9:31 2:36 2:56	helium helium helium helium	30.02 30.02 29.90 29.90	2.0 6.0 2.0 6.0	0.004 0.011 0.004 0.011	1.90 5.50 1.90 5.65	31.07 33.27 30.95 33.07	588 571 824 822	81.25 81.00 78.00 78.00	60 211 51 168	265 317 275 306	Room temperature 76°F
Begin Purge 3:01, Read 3:51 3:51 8:26 8:46	nitrogen nitrogen nitrogen nitrogen	29.90 29.90 29.92 29.92	2.0 6.0 2.0 6.0	0.004 0.048 0.004 0.048	1.85 4.90 1.85 5.10	30.97 33.45 30.99 33.37	846 817 934 894	77.50 77.25 72.25 73.50	50 186 45 173	283 391 276 374	Room temperature 72°F
Begin Purge 8:53, Read 9:25 10:05	helium helium	29.92 29.92	2.0 6.0	0.004 0.007	1.94 6.70	30.95 33.07	916 889	72.50 72.25	44 145	254 279	
Begin Purge 1:17, Read 2:15 8:15 8:21	nitrogen nitrogen nitrogen	29.88 29.89 29.89	6.0 2.0 6.0	0.051 0.018 0.121	6.20 1.50 3.00	33.28 31.14 34.39	1003 69.0 69.0	72.50 68.00 68.00	167 125 293	382 360 424	Power off 2:18, Slow purge over night Room temperature 68°F
Begin Purge 8:24, Read 9:04 9:09	helium helium	29.89 29.89	2.0 6.0	0.007 0.037	1.70 4.60	31.04 33.59	69.0 69.0	68.00 67.75	145 395	368 371	

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 8  
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN C-1, RUN 2

Time	Permeating gas	Atm. press. P <sub>a</sub> in. Hg	Upstream gage press. P <sub>1</sub> in. Hg	Downstream gage press. P <sub>2</sub> (s) in. Hg	Pressure drop through specimen in. Hg	Mean press. P <sub>m</sub> in. Hg	Temperature, °F		Flow rate cm <sup>3</sup> /sec (1)	K <sub>mv</sub> cm <sup>3</sup> /sec	Remarks
							Spec.	Meter			
Begin Purge 10:53, Read 11:53	helium	30.13	2.0	0.004	1.76	31.25	70	69.0	138	341	Room temperature 70°F
11:59	helium	30.13	6.0	0.033	4.70	33.73	69	69.0	384	356	
Begin Purge 12:03, Read 12:25	nitrogen	30.13	2.0	0.011	1.50	31.38	69	69.0	122	354	
12:31	nitrogen	30.13	6.0	0.074	3.13	34.56	69	69.0	280	403	Power on 12:34
7:34	nitrogen	30.10	6.0	0.033	4.67	33.80	662	70.0	201	361	
Begin Purge 7:39, Read 8:00	helium	30.10	2.0	0.004	1.90	31.15	590	70.0	61	277	
8:23	helium	30.10	6.0	0.007	5.54	33.33	569	70.0	203	310	Power up 8:29
10:30	helium	30.14	2.0	none	1.90	31.19	308	71.0	52	284	Room temperature 70°F
10:55	helium	30.14	6.0	0.007	5.64	33.32	775	71.0	172	309	
Begin Purge 11:00, Read 11:25	nitrogen	30.14	2.0	0.004	1.85	31.21	776	71.0	54	296	
11:50	nitrogen	30.14	6.0	0.029	4.97	33.65	727	71.0	188	369	Power up 11:54
3:16	nitrogen	30.06	2.0	none	1.90	31.11	1067	71.0	45	296	Room temperature 71°F
3:40	nitrogen	30.06	6.0	0.018	5.48	33.32	1016	71.0	166	344	
Begin Purge 3:46, Read 4:15	helium	30.06	2.0	none	1.94	31.09	1055	71.0	43	275	
4:40	helium	30.06	6.0	0.004	5.70	33.21	1044	71.0	142	306	Power off 4:44
7:15	helium	30.08	2.0	0.004	1.75	31.20	92	69.0	134	341	Slow helium purge over night, room temp 69°F
7:19	helium	30.08	6.0	0.029	4.77	33.69	77	69.0	381	353	
Begin Purge 7:25, Read 7:58	nitrogen	30.08	2.0	0.011	1.50	31.33	70	69.0	122	360	
8:04	nitrogen	30.08	6.0	0.070	3.18	34.49	70	69.0	286	399	

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 9  
THE PERMEABILITY OF SPECIMEN B-8 AT ROOM TEMPERATURE AND VARIOUS PRESSURES

Time	Gas	Atm press. in. Hg	Upstream press. in. Hg	Pressure drop through specimen in. Hg	Mean press. in. Hg	Press. at flowmeter inlet in. Hg	Flow rate cm <sup>3</sup> /sec	K <sub>mv</sub> cm <sup>3</sup> /sec	Remarks
Run 1 9:20	N <sub>2</sub>	29.41	2.0	.45	31.18	.25	192	1831	Room temperature 72°F
	N <sub>2</sub>	29.41	6.0	1.05	34.93	.70	382	1720	
	N <sub>2</sub>	29.41	9.8	1.45	38.53	1.10	563	1713	
	N <sub>2</sub>	29.41	14.8	1.80	43.31	1.70	718	1792	
	N <sub>2</sub>	29.41	14.9	1.85	43.38	1.75	714	1738	
	N <sub>2</sub>	29.41	20.0	2.20	48.31	2.50	894	1874	
	N <sub>2</sub>	29.41	24.8	2.55	52.93	3.20	1036	1915	
	N <sub>2</sub>	29.41	25.2	2.55	53.33	3.30	1061	1987	
	N <sub>2</sub>	29.41	29.9	2.95	57.63	4.10	1200	1968	
Run 2 12:35 12:40	N <sub>2</sub>	30.08	2.0	.80	31.68	.20	405	2215	Room temperature 65°F
	He	30.08	4.0	1.45	33.35	.30	693	2098	
	He	30.08	6.0	1.85	35.15	.50	914	2182	
	He	30.08	6.0	1.85	35.10	.50	896	2139	
	He	30.08	10.0	2.60	38.78	.90	1348	2320	
	He	30.08	15.0	3.25	43.45	1.50	1778	2497	
	He	30.08	20.0	3.75	48.20	2.20	2205	2743	
	He	30.08	25.0	4.25	52.95	2.90	2578	2888	
	He	30.08	30.0	4.60	57.78	3.75	3004	3193	
Run 3 8:45	N <sub>2</sub>	29.50	2.0	.50	31.25	.30	199	1713	Room temperature 70°F
	N <sub>2</sub>	29.50	4.0	.80	33.10	.45	314	1701	
	N <sub>2</sub>	29.50	6.0	1.05	34.97	.65	402	1668	
	N <sub>2</sub>	29.50	10.0	1.45	38.77	1.10	568	1731	
	N <sub>2</sub>	29.50	15.0	1.85	43.57	1.70	740	1804	
	N <sub>2</sub>	29.50	20.0	2.25	48.37	2.45	904	1855	
	N <sub>2</sub>	29.50	25.0	2.55	53.22	3.20	1044	1936	
	N <sub>2</sub>	29.50	25.1	2.55	53.32	3.20	1020	1889	
	N <sub>2</sub>	29.50	30.0	2.85	58.07	4.10	1193	2033	
	N <sub>2</sub>	29.50	30.0	2.85	58.07	4.10	1199	2042	
Run 4 11:05 11:20	He	29.50	10.0	2.65	38.17	.90	1328	2200	Room temperature 70°F
	He	29.50	20.0	3.80	47.60	2.15	2166	2806	
	He	29.50	30.0	4.70	57.15	3.70	2975	3036	